REMARKS

This is intended as a full and complete response to the Office Action dated October 17, 2006, having a shortened statutory period for response set to expire on January 17, 2007. Please reconsider the claims pending in the application for reasons discussed below.

Claims 8-10, 20-22, 31-33, and 37-59 remain pending in the application upon entry of this Response. Claims 8-10, 20-22, 31-33, and 37-59 stand rejected by the Examiner. Reconsideration of the rejected claims is requested for reasons presented below.

Claims 8-9, 20-21, 31-32, and 37-58 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Miura et al., U.S. Pub. No. 2003-0155247, herein, *Miura*, in combination with *Dubin et al.*, U.S. Pat. No. 6,432,821, herein, *Dubin* and *Wang et al.*, U.S. Pat. No. 6,528,412, herein, *Wang*. The Examiner states that "using PVD and electrolytic copper plating to deposit the copper seed layer is equivalent to electroplating the copper seed layer because they would have been doing the same endeavor," and that the claims are "open to reinforcing the seed layer and adding thickness within trenches or via holes." (Current OA, page 4). The Applicant respectfully traverses the rejection.

Miura discloses a process which provides the deposition of a tantalum nitride barrier layer using a sputtering technique, the deposition of a copper seed layer using a sputtering technique, and the application of electrolytic copper plating to fill or half fill trenches or via holes on the substrate. (see [0059] to [0061]). The Examiner maintains her previous assertion that *Miura* "teaches a method for ***depositing*** a copper-containing seed layer (= ***reinforces*** the seed layer and ***adds thickness to the seed layer*** within the trenches or via holes) [page 4, [0051]] onto a barrier material layer (= a barrier layer) [page 3, [0049]]." (Office Action mailed 05/15/06, page 9).

The Applicant asserts that *Miura* does not teach electroplating a copper seed layer onto a barrier surface. Accordingly, *Miura* discloses that a "conductive ***seed layer is deposited*** on the surface of silicon wafer, or inside the trenches or via holes, ***prior to*** application of ***electrolytic copper plating***." The seed layer is deposited by a PVD

technique or a CVD technique. (see [0049] to [0050]). *Miura* clearly deposits the seed layer by PVD or CVD prior to electrolytic copper plating. Subsequently, *Miura* begins an electrolytic copper plating process in order to reinforce and add thickness to the seed layer. (see [0051]). The evidence proffered by the Examiner is inadequate to support the assertion that the ***seed layer deposited on the surface of a silicon wafer by PVD or CVD techniques prior to the application of electrolytic copper plating***, as disclosed by *Miura*, is equivalent to ***a method for depositing a copper-containing seed layer onto a barrier material layer by an electroplating technique***.

Furthermore, the Examiner has admitted that "Miura teaches that the ***seed layer*** is formed by depositing a layer of a highly conductive metal (e.g., copper) using PVD techniques such as sputtering and ion plating or CVD techniques." (Office Action mailed 05/15/06, page 11, paragraph 3).

Dubin discloses a process to force a first forward current, a second forward current, and a third forward current for depositing an initiation layer, a feature fill layer, and a bulk layer. The process disclosed by *Dubin* includes sequential reverse current steps within a single copper plating solution. The same chemical components are maintained throughout the various steps disclosed by *Dubin*.

Wang discloses a process for forming an adhesion skin layer containing a metal alloy doping element on an underlying material (e.g., barrier or dielectric) prior to forming a seed enhancement layer on the adhesion skin layer and a copper fill layer on the seed enhancement layer. The Examiner maintains her earlier assertion that the invention would have been obvious because the seed layer may be discontinuous, as taught by *Wang*, and the electrolytic copper plating disclosed by *Miura* "would have applied an electrical bias to deposit ***a copper seed layer (= an enhancement seed layer)*** on the barrier surface." (Office Action mailed 05/15/06, page 12, paragraphs 1-2). The Applicant respectfully disagrees with the Examiner's assertion.

The Examiner asserts that the copper seed layer of *Miura* is equivalent to the enhancement layer of *Wang*. However, *Wang* describes throughout the Background that "because the seed enhancement layer 130 is formed by an ECD (electrochemical deposition) ... ***the seed enhancement layer 130 does not adhere as well as the seed layer 122*** ... The poor adhesion of the seed enhancement layer 130 ... is more

likely to result in disadvantageous electromigration failure of the interconnect. On the other hand, a relative thick seed layer 124 has overhang 124 ... which is more likely to result in disadvantageous void formation within the interconnect." (paragraph 3, lines 13-36). *Wang* overcomes the "as known to one of ordinary skill in the art of integrated circuit fabrication," by forming "a thin adhesion skin layer including a metal alloy doping element" on the underlying material prior to forming a seed layer thereon. *Wang* clearly distinguishes between a seed enhancement layer and a seed layer. The Examiner has failed to show a clear and particular motivation for the skilled artisan to combine *Miura* and *Wang*.

The Examiner must supply a clear and particular motivation or suggestion to combine *Miura* and *Wang*. Specifically, the Examiner must show a clear and particular motivation, of one skilled in the art, to combine the deposition of a seed layer onto a barrier layer by *Miura* with the teaching away of *Wang*, which provides depositing ***a thin adhesion skin layer*** including ***a metal alloy doping element*** between the barrier layer and the seed layer.

Therefore, *Miura*, *Dubin*, and *Wang*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a first copper solution comprising complexed copper ions and having a pH value of less than 7, wherein the complexed copper ions are derived from a copper source selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof, applying a first electrical bias across the substrate surface to chemically reduce the complexed copper ions and to deposit a copper seed layer onto the barrier surface and depositing a copper gap-fill layer by exposing the substrate to a second copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 8, and claims 9 and 37-44 dependent thereon.

Also, *Miura*, *Dubin*, and *Wang*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a complexed copper solution comprising complexed copper ions reducing the complexed copper ions with a first electrical bias to form a copper seed layer on the barrier surface, and depositing a copper gap-fill layer by exposing the substrate to a first copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 20, and claims 21 and 45-52 dependent thereon.

Also, *Miura*, *Dubin*, and *Wang*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a complexed copper solution comprising complexed copper ions derived from a copper source selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof, reducing the complexed copper ions with a first electrical bias to form a copper seed layer on the barrier surface, wherein the first electrical bias has a current density of less than about 10 mA/cm^2 across the substrate surface, and depositing a copper gap-fill layer by exposing the substrate to a second copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 31, and claims 32 and 53-58 dependent thereon.

Withdrawal of the rejections is respectfully requested by the Applicant.

Claims 10, 22, and 33 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over *Miura*, in combination with *Dubin* and *Wang*, as applied to reasons discussed above, and further in view of *Nagai et al.*, U.S. Pat. No. 6,709,563, herein *Nagai*. The Examiner asserts that the claimed invention would have been obvious to one having ordinary skill in the art by modifying *Miura* in combination with *Dubin* and *Wang*, and in further view of *Nagai*. The Applicant respectfully traverses the rejection.

Miura, *Dubin*, and *Wang* have been discussed and distinguished above.

Therefore, *Miura*, *Dubin*, *Wang*, and *Nagai*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a first copper solution comprising complexed copper ions and having a pH value of less than 7, wherein the complexed copper ions are derived from a copper source selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof, applying a first electrical bias across the substrate surface to chemically reduce the complexed copper ions and to deposit a copper seed layer onto the barrier surface and depositing a copper gap-fill layer by exposing the substrate to a second copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 8, and claim 10 dependent thereon.

Also, *Miura*, *Dubin*, *Wang*, and *Nagai*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a complexed copper solution comprising complexed copper ions reducing the complexed copper ions with a first electrical bias to

form a copper seed layer on the barrier surface, and depositing a copper gap-fill layer by exposing the substrate to a first copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 20, and claim 22 dependent thereon.

Also, *Miura*, *Dubin*, *Wang*, and *Nagai*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a complexed copper solution comprising complexed copper ions derived from a copper source selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof, reducing the complexed copper ions with a first electrical bias to form a copper seed layer on the barrier surface, wherein the first electrical bias has a current density of less than about 10 mA/cm^2 across the substrate surface, and depositing a copper gap-fill layer by exposing the substrate to a second copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 31, and claim 33 dependent thereon.

Withdrawal of the rejections is respectfully requested.

Claim 59 stands rejected under 35 U.S.C. § 103(a) as being unpatentable over *Miura*, in combination with *Dubin* and *Wang*, as applied for reasons discussed above, and in further view of *Dubin*, U.S. Pub. No. 2004-0108217, herein *Dubin '217*. The Examiner asserts that the claimed invention would have been obvious to one having ordinary skill in the art by modifying *Miura* in combination with *Dubin* and *Wang*, and in further view of *Dubin '217*. The Applicant respectfully traverses the rejection.

Miura, *Dubin*, and *Wang* have been discussed and distinguished above.

Therefore, *Miura*, *Dubin*, *Wang*, and *Dubin '217*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier material layer, comprising providing a substrate having a ruthenium barrier layer disposed on a substrate surface, exposing the substrate to a first copper solution comprising complexed copper ions and having a pH value of less than 7, applying a first electrical bias across the substrate surface to chemically reduce the complexed copper ions and to deposit a copper seed layer onto the ruthenium barrier layer, and depositing a copper gap-fill layer by exposing the substrate to a second copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 59.

Withdrawal of the rejection is respectfully requested by the Applicant.

Claims 39-41, 44, and 52 stand rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the Applicant regards as the invention.

The Applicant thanks the Examiner for pointing out several unclear aspects of the claims. Claims 39-41 and 52 have been amended to clarify the claimed invention.

In claim 44, the recitation of "the barrier layer consists essentially of cobalt, ruthenium, nickel, or tungsten" is consistent with and narrower than the recitation within claim 8 of "the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface." Claim 8 recites that the barrier layer has a barrier surface while claim 44 recites that the barrier layer consists essentially of cobalt, ruthenium, nickel, or tungsten. Also, claim 8 further recites the Markush group of specific material surfaces that may be on the barrier layer. Claim 44 is consistent with and narrower than claim 8.

Withdrawal of the rejection is respectfully requested by the Applicant.

Claims 8-10, 20-22, 31-33, and 37-59 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over *Oskam et al.*, U.S. Pat. No. 6,309,969, herein *Oskam*, in

combination with *Miura*, and *Andricacos et al.*, U.S. Pat. No. 6,974,531, herein *Andricacos*. The Examiner asserts that it would have been obvious to have modified the copper solution described by *Oskam* with the copper salts in a "copper plating solution wherein their anions would not have imposed adverse effects on the electrolytic copper plating solution" disclosed by *Miura*. (Current OA, p. 13). The Applicant respectfully traverses the rejection.

The Examiner asserts that *Oskam* teaches "a first copper 50," "wherein the complexed copper ions are derived from a copper source selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof (=$CuCO_3$ and $Cu(OH)_2$)." (Current OA, p. 11). Then the Examiner states that "Miura does not disclose the following: a. [w]herein the first copper solution contains complexed copper ions, as recited in claim 8. Oskam teaches $CuCO_3$ and $Cu(OH)_2$." (Current OA, p. 13). Therefore, the Examiner realizes that *Miura* lacks disclosure of a copper solution containing complexed copper ions and the Examiner is using *Oskam*'s disclosure of $CuCO_3$ and $Cu(OH)_2$ as disclosure of complexed copper ions. The Applicant respectfully disagrees with the Examiner's assertion.

The Examiner has stated that $CuCO_3$ and $Cu(OH)_2$, as disclosed by *Oskam*, are complexed copper ions, as recited in claim 8. However, $CuCO_3$ is the chemical formula for copper carbonate and $Cu(OH)_2$ is the chemical formula for copper hydroxide. Claim 8 contains a Markush group and recites "a copper source selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof." The Markush group of claim 8 does not recite copper carbonate or copper hydroxide. Furthermore, as the Examiner noted, *Miura* already recites that the copper salt may be copper carbonate or copper hydroxide. (paragraph [0020]).

Also, the Examiner recites a disclaimer taught in *Miura* – that is – "wherein their anions would not have imposed adverse effects on the electrolytic copper plating solution." The Applicant asserts that this statement is so general and broad that it would have been impossible for the skilled artesian to determine copper solution containing the claimed complexed copper ions in view of *Oskam* and *Miura*, as well as

non-obvious, since neither *Oskam* nor *Miura* even disclose any of the claimed complexed copper ions. Furthermore, per this latter recitation, since *Miura* suggests that some anions (e.g., anionic ligands or complexing agents) may impose adverse effects to the copper plating solution, the skilled artesian would need more guidance than provided by the cited references in order to choose anions that do not impose an adverse effect.

Further, the Examiner describes *Oskam* as exposing the substrate to a first copper solution 50, applying a first electrical bias, exposing the substrate to a second or third copper solution and applying a second or third electrical bias. The Examiner asserts that *Oskam* discloses both a copper solution containing the claimed complexed copper ions as well as a copper solution containing free-copper ion. However, the Applicant asserts that *Oskam* only discloses a copper solution 50 and that the Examiner is calling this sole solution a copper solution containing the claimed complexed copper ions as well as a copper solution containing free-copper ion.

The Examiner states that like *Oskam*, *Andricacos* teaches a process for electroplating copper. The Applicant asserts that *Andricacos*, like *Oskam*, discloses an electroplating process by adjusting the current during the deposition process instead of using chemically different plating solutions. *Andricacos* discloses a plating process "employing a plating bath optionally comprising a super filling additive and a suppressor, and by changing the current or voltage as a function of the area of plated metal." (Abstract).

Therefore, *Oskam*, *Miura*, and *Andricacos*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a first copper solution comprising complexed copper ions and having a pH value of less than 7, wherein the complexed copper ions are derived from a copper source selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations

thereof, applying a first electrical bias across the substrate surface to chemically reduce the complexed copper ions and to deposit a copper seed layer onto the barrier surface and depositing a copper gap-fill layer by exposing the substrate to a second copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 8, and claims 9-10 and 37-44 dependent thereon.

Also, *Oskam*, *Miura*, and *Andricacos*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a complexed copper solution comprising complexed copper ions reducing the complexed copper ions with a first electrical bias to form a copper seed layer on the barrier surface, and depositing a copper gap-fill layer by exposing the substrate to a first copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 20, and claims 21-22 and 45-52 dependent thereon.

Also, *Oskam*, *Miura*, and *Andricacos*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier layer, comprising providing a substrate comprising the barrier layer disposed on a substrate surface, wherein the barrier layer has a barrier surface selected from the group consisting of a tungsten surface, a tungsten nitride surface, a titanium surface, a titanium nitride surface, a cobalt surface, a ruthenium surface, a nickel surface, and a silver surface, exposing the substrate to a complexed copper solution comprising complexed copper ions derived from a copper source selected from the group consisting of copper citrate, copper borate, copper tartrate, copper oxalate, derivates thereof, and combinations thereof, reducing the complexed copper ions with a first electrical bias to form a copper seed layer on the barrier surface, wherein the first electrical bias has a current density of less than about 10 mA/cm^2 across the substrate

surface, and depositing a copper gap-fill layer by exposing the substrate to a second copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 31, and claims 32-33 and 53-58 dependent thereon.

Also, *Oskam*, *Miura*, and *Andricacos*, alone or in combination, do not teach, show, or suggest a method for depositing a copper-containing seed layer onto a barrier material layer, comprising providing a substrate having a ruthenium barrier layer disposed on a substrate surface, exposing the substrate to a first copper solution comprising complexed copper ions and having a pH value of less than 7, applying a first electrical bias across the substrate surface to chemically reduce the complexed copper ions and to deposit a copper seed layer onto the ruthenium barrier layer, and depositing a copper gap-fill layer by exposing the substrate to a second copper solution comprising free-copper ions, and applying a second electrical bias across the substrate surface to deposit the copper gap-fill layer onto the copper seed layer, as recited in claim 59.

Withdrawal of the rejections is respectfully requested by the Applicant.

In conclusion, the references cited by the Examiner, alone or in combination, do not teach, show, or suggest the claimed invention.

Having addressed all issues set out in the Office Action, the Applicant respectfully submits that the claims are in condition for allowance and respectfully request that the claims be allowed.

Respectfully submitted,

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